NASA SBIR/STTR Technologies

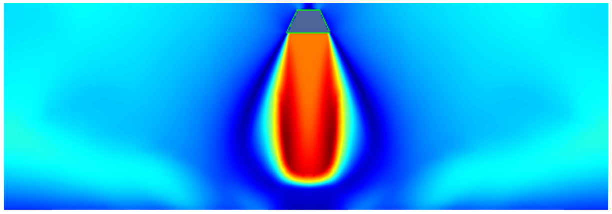
T1.02-9828 - Unified In-Space Propulsion Framework for Prediction of Plume-Induced Spacecraft Environments

PI: Ranjan Mehta
CFD Research Corporation - Huntsville, AL

Identification and Significance of Innovation

Chemical contamination of spacecraft components as well as thermal and force loading from firing liquid propellant thrusters are critical concerns for in-space propulsion applications. Gas molecular contamination and liquid droplet deposition due to incomplete combustion threaten to damage surface materials and sensitive instruments, and poses major risks for mission success. Current CFD modeling capabilities fall short of providing the fidelity required to simulate the contaminant transport around the spacecraft. This STTR effort will develop and deliver a unified computational architecture for prediction of plume flow impingement and contaminant dispersal for in-space propulsion analysis. CFDRC will supplement the NASA massively parallel Loci framework with a highly accurate unified solver for prediction of mixed continuum-rarefied flows with contaminant dispersal. This will enable better understanding and prediction of thermal and force loading and contamination of spacecraft components, and enable design of new era of safer next-generation in-space propulsion systems.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 5)



Prediction of Plume-Induced Thermal and Force loading and Contaminant Transport Environment for In-Space Firing of Thrusters

Technical Objectives and Work Plan

The overall technical objective of this project is to develop an integrated, comprehensive, tightly-coupled physics-based, multidisciplinary simulation tool for prediction of structural response and fluid-induced vibration in turbomachinery components for liquid rocket propulsion systems. The developed tool will couple existing codes written in the massively parallel NASA production Loci framework (Loci/CHEM, Loci/STREAM, etc.), with a nonlinear large-deformation structural solver, CoBi, to solve fluid-structure interaction in turbomachinery applications from first-principles. This coupling will be integrated in the Loci computational framework, and Loci CFD solvers will drive the finite element structural solution in turbomachinery by means of direct invocation of APIs to be created for this purpose. The tool will be rigorously validated against coupled as well as decoupled problems. The specific objectives of the Phase I effort are summarized as follows: a) develop support for constrained deformations in Loci moving overset grid systems; b) develop multidisciplinary turbomachinery coupling interface; c) verification and baseline validation of developed technology; d) demonstration of technology for liquid rocket engine turbopump/inducer applications; and e) deliver and test software on NASA HPC systems, assist MSFC personnel w/applications.

NASA Applications

This technology will be highly beneficial to NASA and its contractors for prediction and analysis of contaminants and particulate transport and interaction in near-vacuum conditions for in-space propulsion applications. Direct NASA applications include supporting spacecraft design with most advantageous thruster placement and design mitigation measures such as shielding through simulation based engineering. Other NASA applications include simulation of effectiveness of RCS thrusters in reentry capsule rarefied wake region.

Non-NASA Applications

Potential Non-NASA government and commercial applications include, assessment of thruster plume induced environments on commercial and military spacecraft, predicting the impact of particles scattered from thruster plumes on ballistic missile and missile interceptor signatures, and optimization of commercial satellite operational life through contamination minimization.

Firm Contacts

Deborah Phipps
CFD Research Corporation
701 McMillian Way Northwest, Suite D
Huntsville, AL, 35806-2923
PHONE: (256) 726-4800
FAX: (256) 726-4806